The Trends of Research in Compressed Natural Gas (CNG) Pressure Vessel Technology: An Overview

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ABSTRACT

The present scenario of the world crisis: price of the fossil fuel has increased. Compressed natural gas (CNG) pressure vessel becomes important in NGV fuel driving system because demand in CNG base has increased and because it is cheaper and more environmental friendly. CNG pressure vessel is suitable for gas operated vehicles which can be made of fully metal, hoop wrapped with metal liner, fully wrapped with metal liner or fully composite with HDPE liner. Fully metal CNG pressure vessel is cheap but it is the heaviest of the pressure vessels compare to others. For lightweight application such as for trucks, buses and taxis, fully composite tanks are more suitable but it comes with a high price. So, many researchers had searched for the best solution to store high volume of CNG with lightweight and cheap material. Even though the aim is clear but the development of CNG pressure tank must follow the standard requirements to prevent failure and minimize the accident. In this paper, the trends of research by manufacturers, research organizations and universities have been analyzed to find the problems and difficulties regarding CNG pressure vessel. The result of the overview showed that all types of tanks had advantages and disadvantages. It depends on the sector and industry concerned which types of CNG tanks are suitable for their usage.

Keywords: CNG tanks, compressed natural gas (CNG), pressure vessel, alternative fuel

INTRODUCTION

Natural gas is becoming an alternative and increasingly attractive fuel for many transportation uses. Fuel costs are significantly less compared to gasoline and the most suitable fuel for bridge is hydrogen fuel. The octane rating of natural gas is about 130, meaning that engines can operate at compression ration of up to 16:1 without "knock" or detonation. Many of the automotive makers have already built transportation with a natural gas fuelling system and the consumer does not have to pay for the cost of conversion kits and required accessories. Most importantly, natural gas significantly reduces CO_2 emissions by 20-25% compared to gasoline because simple chemical structures of natural gas (primarily methane – CH_4) contain one Carbon compared to gasoline (C_8H_{18}) as shown in Table 1. Like methane, hydrogen is a lighter than air, type of gas and can be blended to reduce vehicle emission by an extra 50%. Natural gas composition varies considerably over time and from location to location. Methane content is typically 70-90% with the reminder primarily ethane, propane and carbon dioxide as shown in Table 2[1].

Table 1: Characteristics Comparison Between Gasoline and CNG[4].

	GASOLINE	CNG
Formula	C_8H_{18}	CH_4
Ignition (˚C)	430	700
Octane rating	96	130
Boiling point (Atm. Pressure) (˚C)	27	-162
Air-Fuel Ratio (Weight)	14.5	17.24

Chemical Reaction With Rubber	Yes	No
Storage Pressure	Atm. Pressure	20.6Mpa
Fuel Air Mixture Quality	Poor	Good
Pollution CO-HC-Nox	High	Very Low
Flame Speed (m/s)	0.83	0.63
Combustion ability with air (%)	1-16	4-14

At atmospheric pressure and temperature, natural gas exists as a gas and has low density. Since the volumetric energy density (joules/m^3) is so low, natural gas (hydrogen base gas) can be stored in four types of storage media are currently quoted[2]: (a) liquefied natural gas (LNG) which allows higher volumetric and gravimetric density but requires the liquefaction of natural gas and an efficient insulated vessel to reduce evaporation, (b) natural gas storage [3] materials which the main drawback is the smaller gravimetric density compared with other techniques for an identical efficiency, (c) carbon nanotubes, probably a technology at the early developmental stages, and finally (d) compress natural gas which is review below.

To store in liquefied state (LNG), cryogenic tank is used and temperature at -162°C must be maintained to avoid natural gas from evaporated. It becomes the drawbacks for cryogenic tank because the boil off of LNG can cause excessive pressure built up in cryogenic tanks and boil off natural gas will be vent to the atmosphere to maintain the pressure inside the tank[5].

Table 2: Typical Composition of Natural Gas

CNG contents	Chemical formula	Percentage of CNG content
Methane	CH_4	70-90
Ethane	C_2H_6	0-20
Propane	C_3H_8	0-20
Butane	C_4H_{10}	0-20
Carbon dioxide	CO_2	0-8
Oxygen	O_2	0-0.2
Nitrogen	N_2	0-5
Hydrogen sulphide	H_2S	0-5
Rare Gas	A, He, Ne, Xe	Trace

Cryogenic tanks also required large space compared to CNG pressure vessels. It shows that, LNG is more suitable for heavy duty vehicles such as trucks and buses and not suitable for cars. In Malaysia, CNG were widely used as fuel driving system in public transportation especially for buses and taxis. To store CNG, pressure vessels must be used to hold and store high pressure of compressed natural gas (CNG) at pressure of 200 bars [4].

CNG pressure vessels are manufactured all over the world under various international standards such as ISO 11439:2000, ANSI/IAS NGV 2-1998, ISO 9809-1/1999, ASME Section VIII Div (1) and so on. These standards do specify the requirements to be met during the manufacture of pressure vessels to store CNG. However, the means used to meet these requirements are not specified in any of these standards. For example, base on ISO 11439:2000, it does not provide design formulae nor list permissible stresses or strains, but requires the adequacy of the design to be established by appropriate calculations and demonstrated by testing to show that pressure vessels are capable of consistently passing the materials, design qualification, production and batch tests specified in this International Standard. The design shall ensure a "leakage-before-break" failure mode under feasible degradation of pressure parts during normal service. If leakage of the metal cylinder occurs, it shall be only by the growth of a fatigue crack[6].

All pressure vessels manufacturer must developed their own methodology to check each essential parameter specified in the relevant standards to meet the requirement. For example, if attempt is made based on ASME Section VIII Div (1), the same methodology could also be extended to pressure vessels